The Effect of Meditation on EEG

The Research Synopsis

by

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Abstract

The term *meditation* connotes a process of familiarizing oneself with subjective mental experience and cultivating balanced qualities of mind. Recent longitudinal studies of intensive Focused Attention meditation have demonstrated training-related improvements in attentional stability. Additionally, there is evidence that the general behavioral improvements may be accompanied by functional and structural changes in cortical regions associated with attention and sensory processing. It is possible to explore the benefits of meditation techniques, such as Focused Attention, Open Monitoring, Mindfulness (insight) Meditation Programs like Vipassana, Loving-Kindness Meditation so as to achieve enhancement in cognitive functions. The other advantages of these meditation practices like reduction in stress, depression, anxiety, and increase in happiness, wellbeing are the byproducts. This study proposes to apply these meditation techniques, in particular, to derive benefits for graduate students, and analyze the associated EEG, and physiological data to understand the efficacy of the underlying mechanism. Attainment of the inferences may provide concrete data for the design and development of future academic frameworks.

Introduction

The successful execution of adaptive, goal-directed behavior depends critically on the ability to focus and sustain attention. Individuals vary considerably in their ability to flexibly manage attention in accord with changing situational demands, and even brief lapses of attention can substantially disrupt performance of routine daily tasks[2]. The potential salutary effects of stable attention on mental well-being have long been acknowledged by contemplative traditions, which have developed various mental training techniques thought to increase attentional capacity.

Meditation has roots in the contemplative practices of nearly every major religion. The prevalence of meditation in the media has given the word various meanings. Meditation is the cultivation of basic human qualities, such as a more stable and clear mind, emotional balance, a sense of caring mindfulness, even love and compassion, qualities that remain latent as long as one does not make an effort to develop them. It is also a process of familiarization with a more serene and flexible way of being. Meditative training includes methods for developing enduring psychological traits through deliberate application of awareness to the contents of subjective experience, including thoughts, sensations, intentions, and emotions[3]. Repeated practice of attend- ing to one's experience is thought to cultivate familiarity with and insight into transient phenomenological experiences, leading to lasting changes in cognitive and psychological functioning. Recent longitudinal studies of intensive FA meditation have demonstrated training-related improvements in attentional stability[4].

It is possible to explore the benefits of meditation techniques, such as Focused Attention(FA),Open Monitoring(OM), Mindfulness (insight) Meditation Programs like Vipassana, Loving-Kindness Meditation(LKM) so as to achieve better cognitive functions, in general, and to improve the academic performance of the graduates, in particular. The study of imbibed changes in personality due to intervention of meditation is being done by acquiring EEG, and other physiological signals such as heart rate, respiration rate of the individual.

Literature Survey

There have been growing enthusiasm amongst researchers to explore the various aspects of meditation techniques, its underlying mechanisms and its effects on human behavior and cognition. According to Manish Saggar,et.al (2012), the outcomes from most previous meditation studies were based on cross-sectional comparisons of self-selected participants (i.e., experienced meditators) with only demographically matched controls, making it difficult to draw conclusions about the causal role of meditative practice in any reported differences in cortical activation patterns. There are methodological limitations in the spectral analysis of ongoing cortical activity. Power spectrum estimates are susceptible to contamination by non-cortical sources of noise (e.g., muscle and ocular artifacts). In a study

undertaken by him, participants were randomly assigned to either an initial training group or a wait-list control group. The ongoing cortical oscillatory activity was assessed using spectral analysis of dense-array scalp- recorded electroencephalogram (EEG) data at three assessment points during meditation retreat. The second-order blind source separation along with a novel artifact removal tool, to identify and remove signal sources of putative non-neural origin. Each participant's individual alpha frequency was used to define spectral frequency bands. EEG was acquired at a data sampling rate of 2048 Hz, using the BioSemi ActiveTwo system in an 88-channel equidistant montage. Second-order blind source identification was used to separate sources of contaminating signal from ongoing brain electrical activity. The time-frequency analysis technique based on short-time Fourier transform (STFT) is used. Specifically, is has been predicted that the training-related changes in areas involved in attention and somatosensory processing as evidenced by reductions in alpha- and beta-band power across central and parietal areas of the scalp[4].

In another study of ERP by B. Rael Cahn and John Polich, Participants in the retreat engaged in both periods of concentrative ('focused attention') meditation on breath sensations as well as periods of open-awareness ('open monitoring') meditation on body sensations and the contents of awareness. Behavioral and brain activity from a dichotic auditory oddball and a visual attentional blink task were obtained. The dichotic auditory oddball paradigm involved the presentation of frequent standard tones to both ears with instruction to detect intermittent rare deviant tones, which were presented to either the attended or the unattended ear. Participants were instructed to press a button when such deviants were detected in the attended ear only. In the present study, experienced Vipassana meditators produced a decrease in overall P3a amplitude to distracting stimuli in meditation relative to the control condition, which may index decreased attentional engagement by the frontal cortex [8].

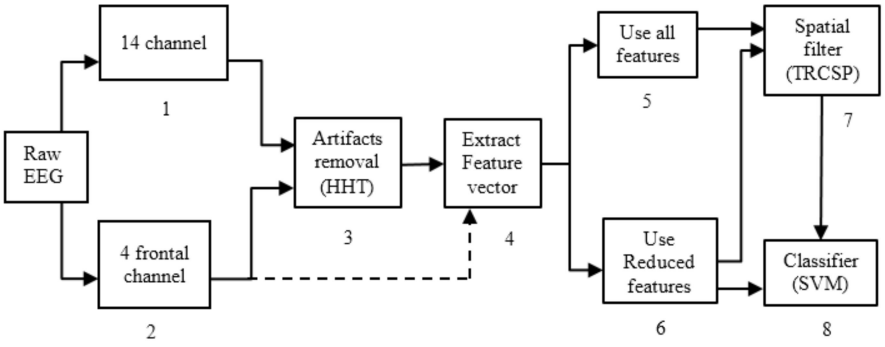
The visual attentional blink paradigm presented visual stimulus sets in quick succession, with target stimulus pairs embedded in the stimulus train and instruction for participants to respond by identifying both embedded targets ('T1' and 'T2'). Previous research has consistently verified that when the second target (T2) stimulus falls in a critical time window after first target (T1), the attentional systems are less sensitive to the incoming T2 stimulus resulting in lower detection performance. The three months of intensive training in Vipassana meditation (a common style of OM meditation) reduced brain-resource allocation to the first target, as reflected in a smaller T1-elicited P3b, a brain-potential index of resource allocation[7].

The physiological basis for enhanced attention has been indicated by Dominique P. Lippelt et.al. as that improved connectivity with the right insula might reflect enhanced interoceptive attention to internal bodily states. In a support of this idea, a recent study reports that mindfulness training predicted greater activity in posterior insula regions during interoceptive attention to respiratory sensation[12]. Increased alpha-theta range coherence has been reported both intra- and inter-hemispherically during meditation[13].

In addition to EEG, respiration is another objective physiological signal that is sensitive to meditation and could be used as an objective measure. Respiration has been shown to slow down without a direct instruction to do so. Slowed breathing has known physiological effects caused by parasympathetic activation, such as decreased oxygen

consumption, decreased heart rate and blood pressure, and increased heart rate variability (HRV)[13].

The frontal and central brain are mostly indicative of Cognitive Load for tasks like problem solving, decision making, and language skills etc. For processing of EEG signals acquired to measure cognitive load, Arijit Sinharay et.al. have used a feature vector comprising of variance, Hjorth parameters, alpha (α), beta (β), theta (θ), delta(δ), gamma (γ) band powers and ratios of band powers β/θ and $\propto/\delta$. For removal of artifacts like eye-blinks, facial muscle movements Hilbert-Huang Transform (HHT) has been used The accuracy of classification can be increased by using a spatial filter. The advanced Tikhonov-Regularized Common Spatial Pattern (TRCSP). Results show that it is possible to get good classification accuracy with Emotiv equipment, if processing steps are chosen properly (shown in fig. below)[6].



(Fig. Block diagram: EEG Signal processing steps [6])

As per the investigations of ERP, by B. Rael Cahn and John Polich (mentioned above), the EEG signal data is subjected to extended ICA algorithm using the runica algorithm implemented within EEGLAB in Matlab. The resultant independent components accounting for horizontal and vertical eye movements were then marked and removed epochs. The data were then organized according to stimulus class (standards, oddballs, distracters) from −1000 ms prior to stimulus to +2000 ms following each stimulus, with the Morlet wavelet decomposition applied to the 3-s epochs time-locked to auditory stimuli. Spectral power was assessed in decibel (dB) units obtained with the log power transformation, $-10 \times \log_{10}(X)$, such that X is absolute power at a given time-frequency point after subtracting the pre-stimulus (−300 to −50 ms) average baseline log-power at each frequency. Data reflecting event-related spectral perturbation and inter-trial coherence (phase locking) were derived from delta (2–4 Hz), theta (4–8 Hz), alpha-1 (8–10 Hz) and alpha-2 (10–12 Hz) frequency bands. The inter-trial coherence and spectral power calculations were obtained using the complex Gaussian wavelet. The wavelet transformation was applied on each single trial and time frequency powers were then averaged across all trials and inter-trial coherence values calculated based on relative phase consistency. The data were then exported to STATISTICA, and repeated-measures ANOVA analyses were performed on the amplitude

and inter-trial coherence values[8]. These EEG signal processing steps shall be exemplary for the proposed task.

It is mentioned that, the neuroelectric (EEG) effects of meditation on brain activity are as yet not well characterized. There is no consensus as to whether evoked sensory and elicited cognitive event-related potentials (ERPs) are altered systematically from long hours dedicated meditators devote to their practice[8]

Emotional regulation is positively associated with academic success in kindergarten middle school and university students, even when controlling for IQ and cognition-related abilities. A conceptual model is put forward based on two propositions: proposition 1)meditation positively influences student success by increasing cognitive functioning; proposition 2)meditation positively influences student success by increasing emotional regulation. Suggestions are made to stimulate future research and to assist in the development of more efficacious applications for meditation in academic premises[9,10,11]

The review of these research articles indicate that the neural correlates of the meditation practices and human cognition, is an open area of research. Also, more systematic efforts are needed to demonstrate and extend the efficacy of meditational techniques to academic environment.

Proposed Nature of Work

Developing an objective measure to assess meditation ability may potentially be done with physiological signals that we know are sensitive to meditation such as EEG and respiration. The spectral coefficients can be employed to develop a classifier for distinguishing between meditation and control conditions.

The exploration of the avenues of meditation in the context of its application to human cognition and well being is to be undertaken. The underlying parameters extracted from EEG signal bands are the representatives of behavioral and cognitive aspects of performance. The EEG data and other physiological parameters can be analyzed to obtain the significant trends..

Following steps are necessary to implement :

1) Signal Acquisition : EEG data using 14-channel, 64-channel (wired/wireless) equipment is to be a acquired. Acquired signal is visually inspected for appropriateness, where major artifacts can be noticed
2) Filtering : The brain rhythms are frequency-specific, (max.50 Hz) and amplitude-specific The maximum amplitude does not exceed 100 μV, hence, shall be filtered, separated.
3) Preprocessing: Raw EEG data is contaminated with high and low frequency noise known as artifacts. High frequency noise is a result of atmospheric thermal noise and power frequency noise. Low frequency noise is primarily caused by eye movements, respiration and heart beats. Artifacts are characterized by amplitudes in the mili-volt
4) Frequency decomposition :The different frequency bands are extracted using wavelet transform and, then the results are interpolated to the length of the given time series taking care of the frequency and, time components simultaneously. These interpolated sequences correspond to the Delta, Theta, Alpha, Beta and Gamma bands

5) Parameter Estimation and Classification : Appropriate features such as Power Spectral Density, Shannon Entropy, Renyl Entropy may be obtained. The Standard Deviation, Mean, Mode may be computed to find the correlation, variance amongst signals or various electrodes. Synchrony studies (phase or amplitude) across signals and electrodes and topographical plots can be obtained. Coherence, or spectral covariance, includes both amplitude and phase in a measure of phase consistency between pairs of signals in each frequency band. Synchrony is a newer approach to measuring the relationship between EEG signals recorded at different electrode sites; this measure quantifies the degree of phase-locking between different narrow band signals[13]

The above analysis shall help in achieving following objectives :

i) To determine(detect) signature effect of FA meditation. Normally, an increased alpha amplitude and decreased alpha frequency in frontal cortex is expected during attentional task. However, signature pattern of FA has not been mentioned, in literature.
ii) To determine(detect) effect of FA,OM, LKM meditation on other physiological parameters, such as heart rate, respiration can be studied, and a correlation across these signals can be obtained
iii) Effects of LKM on meditators/non-meditators can be established.

Expected Outcome :

It is expected that the significant trends hidden under brain rhythms shall be uncovered, which shall be indicative of the signature patterns of meditation techniques. The benefits of meditational practices shall be extended to students and society. The standard patterns obtained through analysis and observation of effects of meditation through brain rhythms may be publicized for larger benefits of individuals, systems.

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